Study Plan: Lake Pleasant Striped Bass

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PROBLEM STATEMENT: Striped bass invaded Lake Pleasant via the Central Arizona Project (CAP) canal system and may out compete other sportfish in the reservoir for the primary prey source, threadfin shad, leading to a decline in the quality and quantity of the sportfish community.

INTRODUCTION / NEED

Lake Pleasant has historically been regarded as one of the premier largemouth bass fisheries in Arizona. However, over the past 15 years, the quality of the largemouth bass fishery has decreased, resulting in low angler satisfaction and a general concern for the health of the fishery (Bryan and Kohagen 2003). The leading viewpoint regarding this decline is that the recent invasion of striped bass may be responsible, in part, for the shift in size structure through competition for resources and predation.

Striped bass initially entered the CAP canal system as eggs or larvae, entrained in Colorado River water pumped from Lake Havasu. Results from a four-year canal study in the late 1980's indicated that there was a growing population of adult striped bass and the potential for their reproduction in the canal would increase as favorable hydraulic operations evolved (Mueller 1989). However, it was thought that reproduction might be limited due to heat induced stress and subsequent mortality. Nevertheless, striped bass quickly found their way into Lake Pleasant soon after it was connected to the canal system in 1992. Striped bass presumably entered the reservoir as eggs or larvae through the Waddell Dam forebay, suggesting that reproduction occurred in the canals. Preliminary results of a recent evaluation of the Lake Pleasant fishery indicate that striped bass abundance is increasing, however it is unknown if the canal continues to act as the sole source of recruitment or whether striped bass are successfully reproducing within the reservoir (Bryan and Kohagen 2003).

Lake Pleasant anglers and fishery managers are concerned that the striped bass population has become established, and will eventually out compete the favored largemouth bass and white bass fisheries by effectively eliminating the primary prey source, threadfin shad. Although studies in some reservoirs have confirmed these fears (Hart 1978; Allen and Roden 1978; Baker and Paulson 1983), others have shown that these predators can co-exist, if properly managed (Combs 1982). Should reproduction be occurring within the lake, extirpation of striped bass from the system is unlikely. Therefore, lake managers will need to develop a plan that allows for the continued prosperity of the largemouth bass and white bass fisheries, while developing and promoting a quality striped bass fishery.

To make the proper decisions for management of the reservoir, the current status of the striped bass population must be properly researched. We propose to address the following objectives with an intensive 3-year evaluation of the striped bass fishery in Lake Pleasant:

i) Determine energetic requirements of striped bass and other pelagic predators in Lake Pleasant to predict the impact on prey resources, and to predict the potential for striped bass population growth in the future.

ii) Determine seasonal spawning movements, habitat preferences and reproductive success and recruitment of striped bass in Lake Pleasant.

iii) Determine whether striped bass move from the CAP canal into Lake Pleasant.

STRIPED BASS LIFE HISTORY

Distribution, Movement & Habitat Use

Natural striped bass populations are generally anadromous, moving from the sea to freshwater to spawn (Merriman 1941; Rulifson and Dadswell 1995), however,

populations introduced into southwestern freshwater reservoirs are typically pelagic dwelling, migrating to tributaries in the spring to spawn and returning to the reservoir where they remain for the summer (Combs and Peltz 1982; Farquhar and Gutreuter 1989). Striped bass seasonal distribution and migrational patterns are mediated primarily by temperature (Bjorgo *et al.* 2000; Mueller and Horn 1999; Combs and Peltz 1982; Haeseker *et al.* 1996; Lewis 1985; Wilkerson and Fisher 1997), however dissolved oxygen (Coutant 1985), light intensity, predation pressure, food availability (Mueller and Horn 1999), and structure (Bjorgo *et al.* 2000) also play a role. Studies have reported that both daily (Coutant and Carroll 1980; Wilkerson and Fisher 1997) and seasonal (Combs and Peltz 1982; Haeseker *et al.* 1996) movement relate to water temperature.

The thermal tolerance range for adult striped bass is 6 – 27 ºC (Merriman 1941), with a preferred range of 18 – 25ºC (Coutant and Carroll 1980; Crance 1984; Coutant 1985). Adults have been found to tolerate temperatures as high as 29ºC, but typically will not survive temperatures above 26 ºC (Mueller 1989). Thermal preference of striped bass is size-specific with juveniles exhibiting a much higher temperature tolerance (35ºC) than adults (Davies 1973; Bryce 1982; Van Den Avyle *et al.* 1983; Mueller and Horn 1999). Large striped bass (> 400 mm TL) are more restricted to cooler waters than small striped bass at elevated temperatures and in stratified conditions (Lewis 1985). McDaniel *et al.* (1993) indicate that some of the likely consequences of thermal stress are inhibited growth, decreased abundance, and lowered survival rates of adult striped bass. Coutant (1985) reported that temperatures greater than 20ºC could affect fecundity.

Dissolved oxygen concentrations also influence striped bass distribution and habitat use (Coutant 1985). Striped bass typically select habitats with dissolved oxygen concentrations greater than 2.5 mg/L (Crance 1984). Several studies indicate that striped bass will occupy higher-than-preferred water temperatures when dissolved oxygen concentrations of cooler waters are low (Zale *et al.* 1990; Farquhar and Gutreuter 1989). Coutant (1985) found that suitable water column habitat for striped bass includes temperatures below 25ºC and dissolved oxygen concentrations greater than 2.0 mg/L.

Daily and seasonal movements of striped bass are often triggered by changes in temperature. Adults will move out of the main reservoir when water temps exceed 25ºC and move into cooler tributaries or areas of ground water inflow with average temperatures ranging between 20 – 22ºC (Schaich and Coutant 1980; Cheek *et al.* 1985). When cooler tributaries are unavailable, striped bass will move to deeper limnetic waters of the reservoir when temperatures rise above optimal ranges (Combs and Peltz 1982; Farquhar and Gutreuter 1989; Matthews *et al.* 1989). Such movement is expected to be typical for striped bass in Lake Pleasant since the Agua Fria is ephemeral, only running in spring, and the reservoir surface temperatures can reach nearly 30ºC during summer months (Bryan and Kohagen 2003).

Even though temperature is the primary factor dictating striped bass distribution within most reservoirs, the distribution of populations are also commonly skewed toward inflow and nursery habitats (Mueller and Horn 1999). Depending on season and habitat conditions, specific densities of striped bass shift among habitats types (Mueller and Horn 1999), and fish will utilize different lake zones (e.g. deep limnetic) when necessary. During spring, prior to stratification, echo-locator charts indicated that fish in the main basin of Lake Texoma, Texas and Oklahoma, were distributed from surface to bottom. With onset of thermal stratification and dissolved oxygen depletion in the hypolimnion, fish move upward in water column and concentrate near the thermocline (Matthews *et al.* 1985). From this vantage, fish can move between the cooler waters of the hypolimnion and the oxygen rich waters of the epilimnion. Once stratified, striped bass in Lake Texoma congregated at depths of 8 – 12 m immediately above the chemocline where the water temp was 28.5ºC and the dissolved oxygen concentrations was 7.2 mg/L (Matthews *et al.* 1985). In Lake Murray during summer, striped bass congregated in the downstream-most reaches of the reservoir, generally in a narrow band of water just above the thermocline that represented the coolest water available but contained sufficient dissolved oxygen for survival (Combs and Peltz 1982; Farquhar and Gutreuter 1989; Matthews *et al.* 1989). During fall and early winter, thermal gradients weaken and fish migrate to deeper habitats, typically deeper than 40 m, however high densities of striped bass still congregated at inflow areas (Mueller and Horn 1999). Braschler *et al.* (1989)

document four behavioral patterns of radio-tagged striped bass: 1) utilization of thermal refuge sites occurred only when water temperature exceeds 28ºC, 2) striped bass can tolerate water temperatures in excess of 28ºC if adequate dissolved oxygen is present, 3) spring migrations out of the reservoirs and into the upstream areas occur when water temperatures reach 13ºC, and 4) fish occur in or around the lake's river channel.

Reproduction

As reservoir temperatures rise in spring, most striped bass move into major tributaries to spawn and return to the reservoir where they remain for the summer (Combs and Peltz 1982; Farquhar and Gutreuter 1989). Spawning will occur at temperatures ranging between 10 – 24ºC but typically peaks at 15 – 20ºC (Setzler *et al.* 1980). Southeastern striped bass initiate spawning activity from early April to late May at 18 ºC (Scruggs 1957; Dudley *et al.* 1977; Bulak *et al.* 1997). Northern anadromous populations of striped bass migrate into freshwater to spawn from April to June when temperatures reach 14 – 21ºC (Pearson 1938; Merriman 1941).

Striped bass broadcast spawn their eggs in surface waters with considerable current or turbulence, where they will remain suspended such that they do not sink to the bottom and become smothered (Goodson 1966; Barkuloo 1970). The number of eggs spawned varies from 15,000 – 40 million per female (Setzler *et al.* 1980). Talbot (1966) found that striped bass incubation periods last from 48 to 71 hours at temperatures between 15.6 – 17.8 ºC. Similarly, Setzler *et al.* (1980) found fertilized eggs hatched at 11ºC and 22ºC hatched after 80 and 29 hours respectively. The size of striped bass fry at hatching ranges 2.0 – 3.6 mm, with average length of 3.1 mm (Carlander 1977).

Diet , Growth & Energetics

Striped bass are typically piscivorous to some extent at lengths greater than 20 mm TL (Sutton and Ney 2002). Juvenile striped bass eat zooplankton at earliest life stages (Tatum *et al.* 1966; Harper *et al.* 1968), and some will continue to do so up to 150 mm TL, however most transition to fish prey at smaller lengths (Sutton and Ney 2002).

Richardson (1982) found that striped bass up to 125 mm TL in Norris Reservoir, Tennessee, consumed zooplankton and aquatic insects, and that fish were not eaten until lengths greater than 120 mm were obtained. Harper *et al.* (1968) found that striped bass as small as 69 mm had added some fish fry to their diet, and by 100 mm, stomach contents primarily consisted of fish. Similarly, Van Den Avyle *et al.* (1983) found that young-of-the-year striped bass consumed primarily larval shad, but also consumed some centrarchids and copepods. Striped bass adults generally prefer soft-rayed, schooling species (Setzler *et al.* 1980) such as threadfin shad, gizzard shad, and alewife (Axon 1979; Crateau *et al.* 1980; Crateau *et al.* 1981; Goodson 1964; Kohler and Ney 1981). Wilde and Paulson (1989) found that threadfin shad comprise the majority of Lake Mead striped bass diet except in spring when seasonal differences in depth and horizontal distribution of striped bass and prey cause spatial separation, causing striped bass to rely on invertebrates. A similar trend was noted by Stevens (1958). Combs (1979) found that seasonal and habitat variations in diet were not significant.

Striped bass feeding patterns are strongly dictated by water temperature, dissolved oxygen concentrations, and prey availability. During daytime in winter, adult striped bass migrate to deeper waters, and are often found schooling on or near the lake bottom. At night they disperse and move to shallower depths near the surface of the water for feeding (Mueller and Horn 1999). Mueller and Horn (1999) observed that striped bass moved to deeper habitats (typically greater than 40 m in depth) during fall and winter. During warm summer months when reservoirs are thermally and often chemically stratified, hypolimnetic water temperatures are preferred, however dissolved oxygen concentrations are often greatly depressed and fall below minimum tolerance levels for striped bass. In contrast, surface water temperatures exceed thermal tolerances. Consequently striped bass are restricted to a narrow window of habitat within or directly above the thermocline. Lewis (1985) typically found striped bass at depths ranging between 5 – 12 m, selecting areas where water temperatures were 20 – 26 ºC with dissolved oxygen concentrations ranging from 3 – 6 mg/L. Schaffler *et al.* (2002) found that during summer months, striped bass in Lake Mary were typically found in pelagic zones between 1 and 10 m from the surface. Threadfin shad and juvenile striped bass are

less restricted by high temperatures and therefore prosper in warmer and more productive surface waters (Mueller and Horn 1999).

Consequences of thermal stress appear to be decreased condition (Crateau *et al.* 1980, Crateau *et al.* 1981, Wooley and Crateau 1983), growth, abundance, and survival rates (McDaniel *et al.* 1993) of adult striped bass. In reservoirs with strong thermal stratification, larger striped bass are isolated from prey leading to decreased body condition, lowered fecundity, and even death. If striped bass are forced to seek thermal refuge, the trade-off is often a limited food supply. At temperatures exceeding 27ºC, striped bass exhibit decreased movement, and may stop feeding (Wawronowica and Lewis 1979; Zale *et al.* 1990), thereby leading to decreased condition. Striped bass have been noted to make excursions of less than two minutes in duration to warmer or cooler water than was generally occupied (Coutant and Carroll 1980). Striped bass most likely make these short excursions to search for prey. Striped bass in St. Johns River, Florida had significant differences in weight – length regression slopes between summer and winter seasons indicating larger fish (> 500 mm TL) experienced decreased condition during summer compared to winter. Small fish were less affected by the high summer temperatures and did not exhibit as marked of loss in condition as did large fish (McDaniel *et al.* 1993). Regardless, all striped bass were less robust in summer than winter.

Striped bass growth rates are closely tied to temperature and prey availability (Cox and Coutant 1981). Northern populations exhibit slower growth than southern populations due to the shorter growing season, and temperature differences (Magnin and Beaulieu 1967). Juvenile growth rates are rapid and increase with temperature (Rogers and Westin 1981). Growth rates of all size classes are positively associated with prey availability; growth is slow when prey is unavailable (Axon 1979), and rapid growth occurs when prey is abundant (Collins 1982). Striped bass exhibited reduced growth rates as shad declined in Lake E.V. Spence, Texas (Morris and Follis 1978).

Population Dynamics

Communities expand and contract with changes in nutrient inputs, primary production and spawning success. When primary production is high, the result is felt throughout the entire food chain. Striped bass respond rapidly to such conditions leading to rapid increases in fecundity and biomass which can, in turn, lead to over cropping of prey, and eventually, a striped bass population crash. When the trophic structure of a community is simple (one prey), boom and bust phenomena becomes even more pronounced (Axon and Whitehurst 1985). In such food chains predators are heavily dependent on a single prey species, and oscillations in the predator population tend to lag a year or more behind those in the prey population (Odum 1959). Threadfin shad and striped bass populations are extremely cyclic because their reproductive capability allows them to respond rapidly to changes in their environment (both positively and negatively; Adams *et al.* 1982; Adams and DeAngelis 1987; Hale 1996; Michaletz 1997, 1998; Sammons *et al.* 1998) such that the forage base will be sufficient in some years and insufficient in others to support higher trophic levels (Cyterski *et al.* 2003). In Lakes Mead and Powell, boom and bust cycles are predictable on a 3 – 4 year timeline (Mueller and Horn 1999).

In systems having multiple predators competing for a limited prey base, predator-prey dynamics of striped bass and their prey can indirectly effect the entire community. Studies show cases where striped bass populations have no effect on clupeid populations and other predators in the system (Combs 1982). However, in other systems introduced striped bass populations have resulted in marked declines in numbers and biomass of prey as well as other predators. For example, declines in threadfin shad and rainbow trout in Lake Mead have been attributed, in part, to predation by striped bass (Allen and Roden 1978; Baker and Paulson 1983). Gizzard shad populations in Smith Mountain Reservoir, Virginia declined following introduction of striped bass (Hart 1978).

Habitat overlap between striped bass and largemouth bass is generally minimal but both species tend to be abundant near shore early in the growing season (Sutton 1997) and diet overlap may lead to competition for prey during early life stages (Sutton and Ney 2002). Once both species become piscivorous, habitat overlap is minimal. Largemouth bass are

generally collected near shore in areas with structure (Sutton and Ney 2002) and often target littoral prey species such as sunfish. In contrast, striped bass move offshore into pelagic waters once their diet switches to fish. Striped bass and largemouth bass also exhibit differences in foraging behavior, further minimizing competition potential. Striped bass actively search for and pursue prey in schools, often giving rise to water boils commonly seen by anglers. Schooling behavior is suited for locating patchily distributed schooling prey such as clupeids (Mensinger 1971; Matthews *et al.* 1988). Largemouth bass employ sit-and-wait strategies, often utilizing submerged structure afforded by littoral habitats (Winter 1977; Ward and Neumann 1998). In Smith Mountain Lake, age-0 striped bass and largemouth bass of piscivorous sizes appear to be trophically compatible. It is worth noting, however, that in this system, more than two types of prey are available to predators. The study supports the conclusions of Stevens (1958) and Ware (1975) that striped bass are not significant predators on game fish populations in warmwater reservoirs and their tailwaters (Combs 1979).

STUDY AREA

Lake Pleasant

Lake Pleasant is a water storage reservoir located approximately 50 km northwest of Phoenix (Figure 1). The original dam was built in 1927 for the purpose of irrigation and water storage for Maricopa Water District. Increasing demands prompted the United States Congress to authorize the Bureau of Reclamation (USBR) to construct the Central Arizona Project (CAP) in 1968 (Public Law 90-537) for the purpose of transporting water from the Colorado River to Central Arizona to meet these increasing water demands. Lake Pleasant was the logical location for water storage due to its proximity to the Phoenix metropolitan area, the greatest concentration for water demand in the state. Since the storage capacity of Lake Pleasant was not enough to meet CAP needs, USBR proposed the construction of the New Waddell Dam, the building of which commenced in 1985 and ended in 1992. After the old dam was breached, the surface area of Lake Pleasant nearly tripled from 3760 acres to 9970 acres, and storage capacity increased from 157, 000 to more than 1.1 million acre-feet. Water is pumped into and out of the

reservoir through the same intake structure located at the dam. Water is typically pumped from the canal into the reservoir from November to April, after which the water elevation is maintained until water consumption exceeds that available through the canal system alone, and water is subsequently pumped out of the reservoir (Personal communication, Doug Crosby, Central Arizona Water Conservation District). The high water demand results in a substantial changes in reservoir water elevation between summer and winter months. The Agua Fria and several small tributaries supply seasonal inputs to the upper portion of the reservoir.
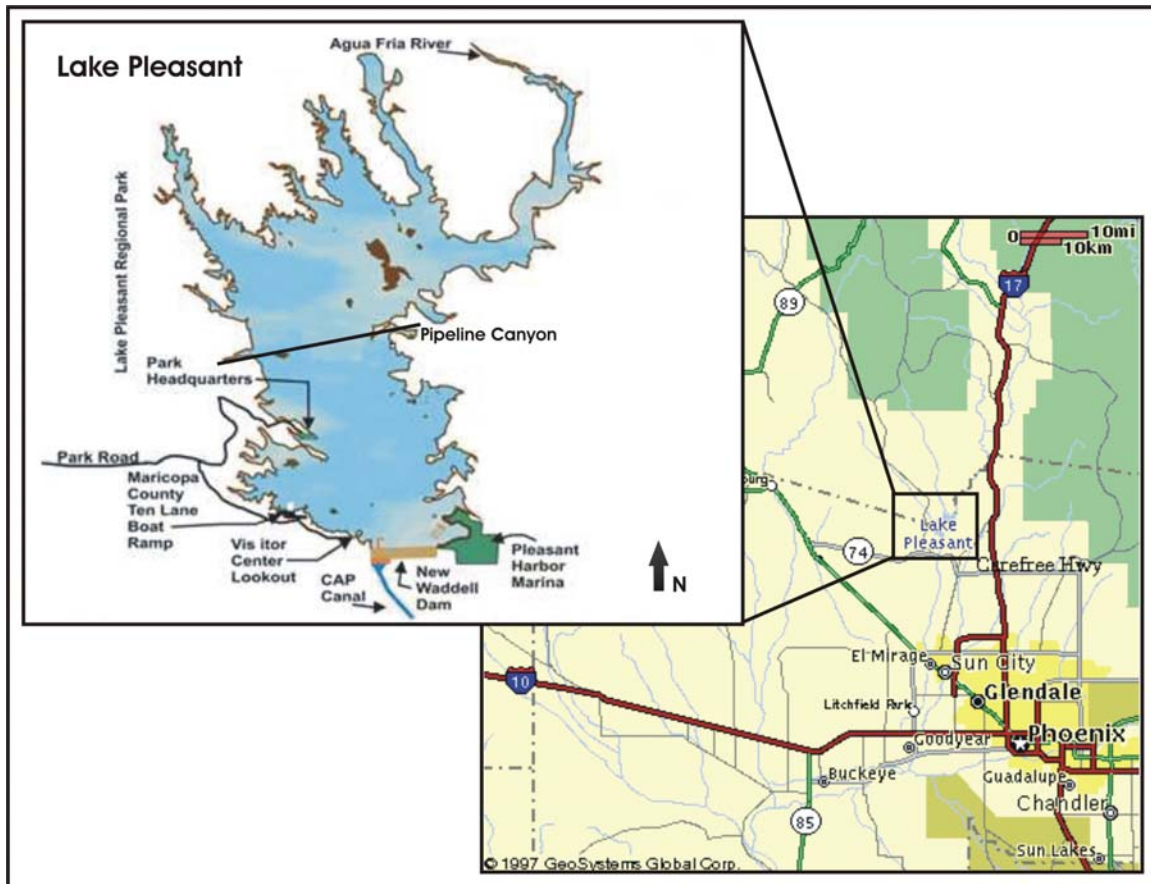
Figure 1. Lake Pleasant is located approximately 50 km northwest of Phoenix, Arizona. The CAP canal connects to Lake Pleasant at the south end of the reservoir, and the Agua Fria and several tributaries flow in from the north. Pipeline Canyon is considered to be the dividing line between the upper and lower basin.

Lake Pleasant is monomictic; it turns over once in the fall and remains mixed until late spring when ambient temperatures increase and the reservoir stratifies. The mean thermocline depth is approximately 3 – 12 m beginning in April and lasting through late

fall, and temperatures range from 10 – 30 ºC (Bryan and Kohagen 2003). During summer dissolved oxygen concentrations in the hypolimnion are typically depressed to less than 1 mg·L^{-1} (Bryan and Kohagen 2003). The reservoir is mesotrophic during spring months and oligotrophic during the remainder of the year, with most nutrients entering the system via the Agua Fria (Bryan and Kohagen 2003). Fish species present in the reservoir include largemouth bass (*Micropterus salmoides*), flathead catfish (*Pylodictis olivaris*), channel catfish (*Ictalurus punctatus*), carp (*Cyprinus spp.*), white bass (*Morone chrysops*), striped bass (*Morone saxatili*s), threadfin shad (*Dorsoma petenense*), green sunfish (*Lepomis cyanellus*), bluegill (*Lepomis macrochirus*), redear sunfish (*Lepomis microlophus*), tilapia (*Tilapia* spp.), golden shiner (*Notemigonus crysoleucas*), red shiner (*Cyprinella lutrensis*), white crappie (*Pomoxis annularis*), and black crappie (*Pomoxis nigromaculatus*)*.*

CAP Canals

The CAP canal was connected to Lake Pleasant following the completion of the New Waddell Dam in 1992. The canal extends 541 km from Lake Havasu to the southern boundary of the San Xavier Indian Reservation, south of Tucson (Figure 2), and is concrete-lined with a bottom width of 25.4 m to 27.2 m, and an average water depth of 5 m. The Waddell pumping station is approximately 225 km downstream from Lake Havasu, and water flows from the main canal through the Waddell Canal (~ 8 km in length) before going through the Waddell pumping plant and entering Lake Pleasant. The New Waddell Pump/Generating Plant has 4 pumps and 4 pump/generators with a total pumping capacity of 3,000 cubic feet per second. The water is lifted 59 m from the canal through the pumping station into Lake Pleasant. On average, 1.5 million acre-feet of water is transported through the canal system each year.

Mueller (1989) collected seventeen fish species in the CAP canal system during 1986 – 1989; most of these species were entrained during early life stages. His data suggests that

Figure 2. The Central Arizona Canal extends from Lake Havasu to the southern boundary of the San Xavier Indian Reservation. The water flows a total distance of 541 km, through 15 pumping plants. Lake Pleasant is located approximately 225 km downstream from Havasu Inlet.

striped bass fry and larvae enter the canal system from Lake Havasu at extremely low rates; two years of egg and larval collecting efforts produced no striped bass larvae and only five eggs collected in 1987 (Mueller 1989). This low entrainment rate likely occurs since the Havasu Pumping Station is not located in an important striped bass spawning area, therefore striped bass larvae and eggs are less likely to be entrained when water is pumped into the canal system (Mueller 1989).

The rate of adult fish passage through the Lake Havasu pumping station into the canal system is approximately 2 fish per hour or 0.00002 fish·m^{-3} (Mueller 1989). The pumping structure has no obstruction to fish passage and turbine pumps are not equipped with wicket gates; however, the likelihood of fish swimming through idle turbines and

successfully passing through operating pumps is low (Mueller 1989). Ninety-five percent of the fish that passed through the Lake Havasu pumping station were dead (Mueller 1989). Fish less than 51 mm TL are susceptible to entrainment from intake velocities found at the Lake Havasu pumping plant (Grabowski *et al.* 1984), and calculations indicated it would be physically possible for fish up to 305 mm in length to successfully pass through the Lake Havasu pumping station (Grabowski *et al.* 1984). These calculations were found to be invalid as Mueller (1989) documented successful passage of striped bass and other fishes up to 510 mm. Mueller (1989) and R. Clarkson (USBR, personal communication) suggest that larger fish may pass through pumping stations by occupying the intake chamber prior to pumping, and being carried through as pumping commences.

During 1986-1989, the species composition of the CAP Canal system mirrored that found in Lake Havasu, and threadfin shad was the most abundant fish species collected (Mueller 1989). Similar to Lake Havasu, gill netting and electrofishing surveys indicated that striped bass comprised less than 5% of the fish community in the CAP canals (Mueller 1989). The striped bass community was primarily composed of age 1 – 3 individuals. Older fish were likely not present due to higher susceptibility to heat induced stress and mortality. The average mean length of striped bass increased annually throughout Mueller's study suggesting an increase in the number of sexually mature adults within the canal system, and consequently an increase in the likelihood that striped bass were able to spawn in the canal. This was confirmed when ripe females and milting males were commonly found in the canal in the later years of the same study (Mueller 1989). If striped bass reproduction is occurring in the canal, recruitment is likely to be greatly diminished by susceptibility of eggs and larvae to downstream drift and predation.

OBJECTIVES & METHODS

The results of this study will predict how the presence of striped bass in Lake Pleasant impacts the white bass and largemouth bass fishery, and the primary prey species, threadfin shad. Management strategies will be developed with the goal of minimizing the

negative impact striped bass may have on the existing fishery. The following objectives and methods will address the primary objectives stated in the introduction and will include determination of striped bass reproduction, movement, diet, growth, and predator-prey relationships within Lake Pleasant.

OBJECTIVE 1.0   DETERMINE ENERGETIC DEMANDS OF STRIPED BASS, WHITE BASS, AND LARGEMOUTH BASS IN LAKE PLEASANT TO ASSESS THEIR EFFECT ON PREY RESOURCES (ESPECIALLY THREADFIN SHAD), AND TO PREDICT THE POTENTIAL FOR GROWTH OF THE STRIPED BASS POPULATION.

Changes in community structure are complex and often influenced by multiple factors such as predator-prey dynamics, introduction of new species, and environmental conditions. Consequently, it is often difficult to distinguish the primary factors causing a shift in community composition. This is likely to be the case for Lake Pleasant, as it will be difficult to determine whether the newly-introduced striped bass population is causing the observed changes in the fish community, or whether the system is still responding to environmental changes brought on by the increase in nutrient load as a result of the completion of New Waddell Dam.

Organisms must share limited resources in order for competition to occur (Smith 1990). If a new predator species is introduced into a system, and it is a more aggressive competitor, or it's density becomes sufficient to decrease prey availability, other fishes relying on the same prey resource may experience a diet shift, and/or reduced consumption, growth, condition and biomass. Such responses are often indicators of competition in systems where *Morone* species have been stocked (Jenkins and Morais 1978; Crandall 1979; Morris and Follis 1978) or reproduced naturally (Stevens 1979; Gustaveson *et al.* 1984). Prey depletions caused by striped bass in these studies may have affected coexisting predators that depended at least partially on the same resources.

Because quantifying predator-prey interactions, competition, and resource use by individuals, populations, and communities is difficult, biologists must rely instead on indirect evidence. Bioenergetics modeling is a tool commonly employed to quantify predator trophic demand and relate demand to prey supply (Ney 1990) allowing

biologists to estimate growth and consumption of individuals, cohorts, populations, and even fish communities. Such models are based on an energy budget equation whereby energy consumed is partitioned into growth, metabolism, and waste products (Winberg 1956). The model requires species specific physiological estimates of physiological data (energy densities of striped bass and prey; physiological parameters of striped bass relating to temperature dependence and allometric weight functions) and site-specific information (water temperature, diet composition, growth, mortality, and population size; Kitchell *et al.* 1977).

Striped bass are known to be aggressive predators and may potentially reduce threadfin shad such that the more preferred sportfish in the system, white bass and largemouth bass, may become prey-limited, leading to decreased growth, condition, fecundity, and potentially abundance. Possible negative interactions with *Morone* species include direct predation on sport fishes, and competition (Raborn *et al.* 2002). Most studies report no predation on sport fishes by striped bass (Matthews *et al.* 1988; Moore 1988; Mann 1995, Raborn 2000) and others consider it rare and inconsequential (Combs 1979). Raborn *et al.* (2002) used bioenergetics models to estimate annual striped bass prey consumption in Norris Reservoir, Tennessee and found that even complete removal of the striped bass population would not measurable increase the biomass of other sportfish.

To assess predator-prey dynamics in Lake Pleasant, we will determine consumption by pelagic prey fishes (striped bass and white bass) in the reservoir using the Wisconsin fish bioenergetics model (Fish Bioenergetics 3.9; Hanson *et al.* 1997). We will assess the energetic demands of the Lake Pleasant pelagic predator community as a whole rather than for each species since hydroacoustic technology is not yet available to identify among species. Data needed for the bioenergetics model will be collected via hydroacoustic (population number and biomass), gill netting (species composition, diet, growth), and water quality surveys (temperature profiles). Energy content of predators and prey will be taken from literature. The following Sub-Objectives indicate how we will collect data required by the model.

Research Hypothesis: Lake Pleasant striped bass, white bass and largemouth bass consumption demands are currently being met by the prey community.

1.1 Water Quality Parameters

We will collect depth/temperature profiles, specific conductance, dissolved oxygen, pH, turbidity, and chlorophyll a measurements during spring, summer and fall/winter at three stations routinely monitored in the Lake Pleasant Phase II study (Scott Bryan, personal communication), plus at one station in the Agua Fria during (Figure 3). Stations are located near the channel since striped bass are often associated with current and areas of inflow (Lewis 1985). A YSI 6920 Sonde and YSI 610 Display/Logger will be used to measure and record temperature (ºC), specific conductance ($\mu S \cdot cm^{-1}$), dissolved oxygen ($mg \cdot L^{-1}$) and pH at 1 m depth intervals at each station. Light penetration will be estimated using a secchi disk. Water turbidity will be measured using a HACH 2100P Turbidimeter. A Kemmerer Bottle will be used to collect a water sample from within 1 m of the surface for chlorophyll a analysis. Samples will be filtered in the field through a Whatman GF/F glass fiber filter (0.7 μm). Filters will be wrapped in foil, placed on ice, and transported to the lab where Chlorophyll *a* concentrations ($\mu g \cdot L^{-1}$) will be measured fluorometrically following extraction into acetone (detection level of 0.005 mg/L) and corrected for phaeo-pigments.

Six Hobo thermisters will be deployed during early spring and programmed to log water temperature for up to one year. Thermisters will be anchored to permanent buoys in the upper and lower basins in the epilimnion, thermocline and hypolimnion (i.e. three upper, three lower).
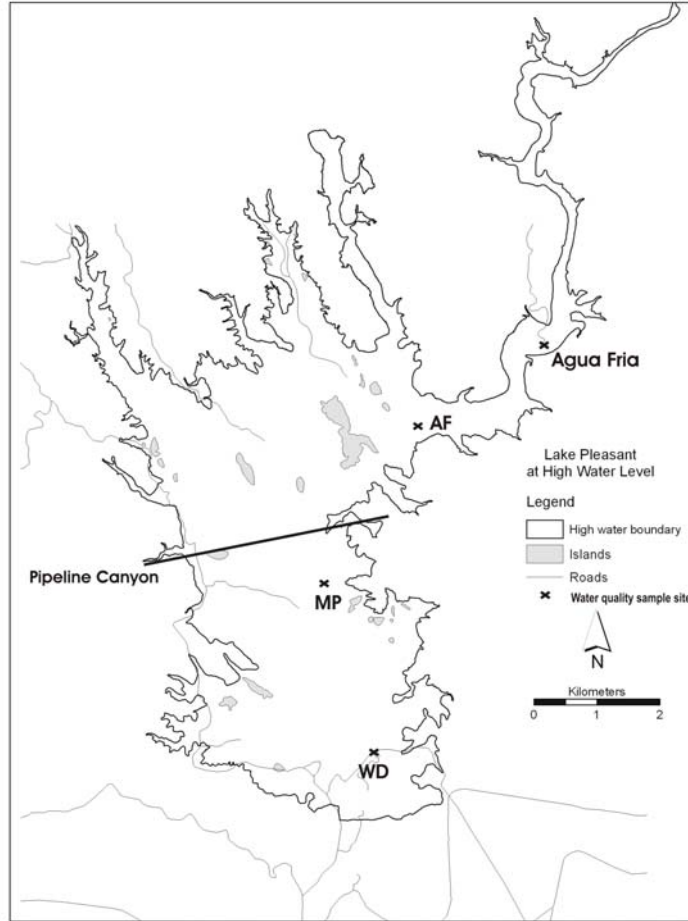
Figure 3. Four water quality stations will be sampled during spring, summer and winter. AF, MP and WD are three of eight stations that were routinely monitored in the Lake Pleasant Phase II study. A station located in the Agua Fria will be added.

1.2 Estimate pelagic predator (striped bass, white bass) and prey (threadfin shad) biomass and density using hydroacoustics.

Using a mark-recapture method of estimating population sizes for predators (and prey) is not feasible in Lake Pleasant due to the size of the reservoir and the large number of fish available. Although hydroacoustic technology is not yet able to discern among species, we are confident that we can use it effectively to assess the biomass and density of the Lake Pleasant pelagic predator population (Mueller and Horn 1999; Fleischer *et al.* 1997; Boxrucker 1996; Cyterski *et al.* 2003). We will conduct hydroacoustic surveys during early spring (pre-spawn) and fall to estimate pelagic predator densities in Lake Pleasant. These estimates will then be used in

conjunction with bioenergetics modeling to estimate energetic requirements of predators in Lake Pleasant.

Late summer hydroacoustic surveys provide estimates best reflecting annual fish production. However, the most appropriate time to estimate brood stock levels of striped bass and threadfin shad is in late winter/early spring, before fish move out of deep habitats to spawn (Gordon Mueller, personal communication). Assessing pelagic fisheries prior to spawning also allows for better determination of density since fish are larger and discriminating between large and small (i.e., prey vs. predator) fish will not be as problematic. Therefore we will conduct hydroacoustic surveys of the Lake Pleasant pelagic fish community during February and August of 2005 and 2006.

In late winter, striped bass typically migrate into deeper habitats during the day and school at depths greater than 40 m, usually in association with the lake bottom (Mueller and Horn 1999). This behavior makes it is difficult to distinguish between individual targets using hydroacoustics, resulting in underestimates of fish density. However the overall biomass estimate is likely to be more accurate. At evening and night, striped bass rise and disperse to feed, allowing for easier detection of individual fish targets and determination of size distribution. Daytime surveys indicate pelagic fish community biomass, and nighttime surveys will indicate the pelagic fish community density and size distribution. We will conduct both day and night hydroacoustic surveys during February and August of 2005 and 2006. Since threadfin shad should be the only small bodied species occupying pelagic waters in Lake Pleasant, we will attempt to discern between predator and prey fish. Hydroacoustic surveys will be run in conjunction with gill netting surveys to validate predator and prey composition and fish size distributions.

For purposes of analysis, pelagic water will be defined during preliminary sampling. Analysis will start at the ping where pelagic water is considered to start. Mean target strength (dB) of fish targets will be transformed into mean fish length based on

Love's equation (Love 1977). This equation accounts for various orientations of individual targets in the water column (Cyterski *et al.* 2003). We will measure lake water volume and estimate fish density (fish/ha) and biomass (kg/ha). According to Mueller and Horn (1999), echo integration is the best method of estimating fish biomass for schooling species or high density communities. This is done by summing the total amount of energy reflected back by all targets and dividing by average target strength, to yield individual target measures.

Lake Pleasant Phase II data suggests the maximum prey size available is 200 mm TL, and the minimum striped bass, white bass, and largemouth bass sizes detected by electrofishing surveys and in gill nets is approximately 200 mm (Scott Bryan, unpublished data). Since we are limiting our estimate to the pelagic waters we assume juvenile largemouth bass, striped bass and white bass will not be present since they select for shoreline habitats with cover. Since fish located within 1 m of surface cannot be detected, and detection is limited in the top 10 m of water because of the cone shape of the signal, estimates should be considered conservative.

1.3 Determine Pelagic Fish Relative Abundance, Percent Composition, Diet and Growth via Gill netting.

Gill netting will allow us to estimate the percent composition and relative abundance of Lake Peasant's pelagic fish species, and enable us to collect diet and age/growth information required by the bioenergetics model. Water depths considered to be pelagic will be determined during preliminary sampling. A stratified random design will be employed whereby a 50 x 50 m grid will be superimposed on Lake Pleasant (Figure 4). Sites will be randomly chosen and gill nets will be set at these locations. If a quadrant is located in unsuitable waters (i.e. not pelagic), the next randomly chosen site will be selected, until a suitable site is found. Gill nets will be set horizontally in the water column at the surface and thermocline (during summer when reservoir is stratified) since striped bass are expected to school immediately above the thermocline during summer.
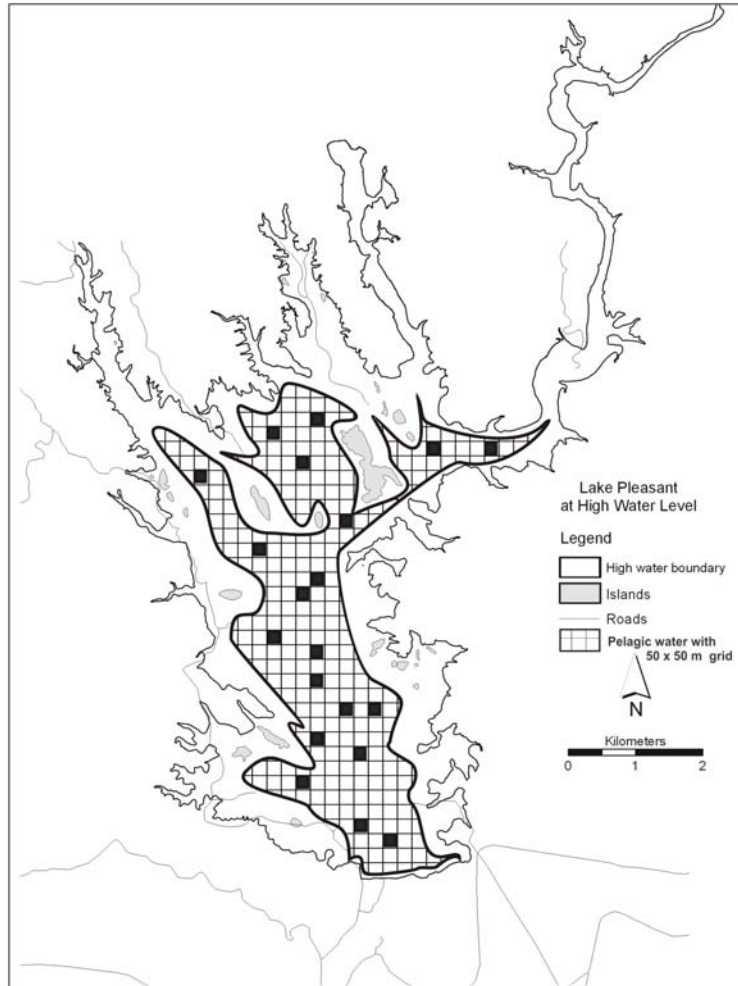
Figure 4. Sample sites (■) will be randomly selected within pelagic waters. Sites will be 50 m x 50 m. This illustration is not drawn to scale, and does not accurately represent Lake Pleasant pelagic water or sample quadrant sizes.

In winter, striped bass are expected to disperse and migrate to deep waters during daytime and migrate to the surface in the evening and night to feed. A minimum of thirty (10 surface, 10 thermocline, and 10 bottom) pelagic quadrants will be sampled during spring, summer and fall/winter of 2004 through 2006 (the first sampling effort will take place in August of 2004). If the target sample size of 10 striped bass and white bass per each 50 mm total length group is not met, additional gill nets will be set at locations where striped bass are known to be present. Data from these net sets will not be included in relative abundance estimates. All nets will be set in the early evening and will be retrieved after approximately twelve hours. If stomach contents

are digested past the point that species identification is possible, or a large number of stomachs are empty, the duration of the net sets will be shortened. Nets are 55.38 x 3.08 m experimental monofilament gill nets with 6 panels of varying bar mesh size (12.7, 25.4, 38.1, 50.8, 63.5, and 76.2 mm).

All captured fish will be identified to species, measured (TL ± 1 mm), weighed (± 1 g), and examined externally for general health and condition. We will record the net depth and mesh in which each fish is caught. We will collect striped bass and white bass scales from the region between the dorsal fin and lateral line. A minimum of 10 striped bass and white bass from each 50 mm length category will be sacrificed and sagittal otoliths will be collected; both scales and otoliths will be placed in a scale envelope and returned to the laboratory for aging (Sub-Objective 1.2.1). Stomachs will be removed and placed in a whirl-pak, fixed with 10% formalin and returned to the laboratory for analysis (Sub-Objective 1.2.2). A minimum of 200 threadfin shad will be retained, fixed in formalin and returned to the lab to develop relationships between total length, and caudal – atlas length measurements, etc., such that total length and weight can be calculated for partially digested fish.

Catch-per-unit-effort (CPUE) and percent composition will be calculated for each fish species as:

$$CPUE = \frac{number\ of\ fish\ caught}{effort\ in\ hours} \qquad (1)$$

$$\%\ Composition = \frac{species\ CPUE}{total\ CPUE} * 100 \qquad (2)$$

Relative weight (W_r) and PSD indices will be calculated for each species. W_r will be regressed on total length to identify size-dependent trends in condition.

1.3.1   Fish Age, Growth and Mortality

The greatest success in aging striped bass has been with scales, and validity of counts can be verified from length frequencies (Crateau *et al.* 1981). In Florida, striped bass annuli are observed to form in summer when growth slowed as temperatures > 26ºC (Crateau *et al.* 1981, Wooley and Crateau 1983). Annuli formation occurred between December to February in Oklahoma (Erickson *et al.* 1972). We anticipate Lake Pleasant striped bass will form their annuli during summer months since water temperatures exceed the optimal growth range during this time, and growth is likely to slow. We will age striped bass with scales, and white bass will be aged with otoliths. We will attempt to verify striped bass age determined from scales with otoliths, however previous attempts to age striped bass with otoliths have been unsuccessful (Scott Bryan, personal communication). Scales will be mounted and viewed with a dissecting scope and/or microfiche. Otoliths will be placed in glycerol for no longer than 10 days, washed with water, dried and transferred to vials. Otoliths will be read in whole view or sectioned and mounted depending on clearness of annuli. Scales and otoliths will be read by two independent readers. Annuli on both scales and otoliths will be digitized and fish length-at-age will be back-calculated. Fish age will be assigned according to DeVries and Frie (1996).

Catch curves will be generated for each species, and instantaneous mortality rates will estimated by regressing the descending portion of the catch curve following a natural log transformation (Maceina 1997).

1.3.2 Diet Analysis

Stomach contents will be removed, identified to species (when possible) and enumerated. If total length is not measurable, prey fish will be measured from the atlas to the caudal bone, and converted to total length using the relationship developed from the threadfin shad collected during gill netting. A length-weight relationship will then be used to determine prey weight for use in the bioenergetics model.

To quantitatively describe pelagic predator fish diet, frequency of occurrence (number of fish with diet taxa in stomach), percent composition by number (number of each diet taxa divided by total number of individuals), and percent biomass of each diet taxa will be calculated for each prey type. The biomass of threadfin shad consumed will be calculated using a weight-length relationship developed from Lake Pleasant threadfin shad collected in gill nets.

1.4   *Fish Bioenergetics Modeling*

Energetic demands of predator fish and prey will be modeled for the average fish in each age class the Wisconsin fish bioenergetics model (Fish Bioenergetics 3.9; Hanson *et al.* 1997) . Should aging not be possible, fish will be grouped according to life history traits (e.g. sub-adult and adult), and the average fish of each class will be modeled. Consumption will then be extrapolated for the reservoir using population estimates derived from the hydroacoustic surveys.

OBJECTIVE 2.0   DETERMINE SEASONAL MIGRATIONAL SPAWNING MOVEMENTS, HABITAT PREFERENCES AND REPRODUCTIVE SUCCESS OF STRIPED BASS IN LAKE PLEASANT.

Since striped bass are relatively new inhabitants of Lake Pleasant, their seasonal movements, habitat preferences, and spawning success remain unknown. To learn behavioral patterns of Lake Pleasant striped bass, we will implant either radio or ultrasonic tags in subadults and adults and monitor their movements via telemetry, as well as perform egg and larval tows, and set larval light traps within the reservoir and Agua Fria to identify spawning success.

Research Hypothesis: Striped bass reproduce naturally in Lake Pleasant. They migrate up the Agua Fria in spring to spawn and return to the main reservoir. In winter, striped bass occupy deep pelagic waters and during summer they occupy the coolest available pelagic waters having sufficient dissolved oxygen concentrations, most likely near the thermocline.

2.1 Determine striped bass seasonal migration patterns in Lake Pleasant.

Fifteen adult striped bass will be collected from Lake Pleasant using both angling and gill netting during spring, 2005 prior to spawning. According to Gustaveson *et al.* (1984) striped bass in Lake Powell remained in large schools in a pre-spawn staging area prior to spawning. We anticipate that Lake Pleasant striped bass will exhibit similar staging behavior in the Agua Fria, during March to April, or until water temperatures in the reservoir approach 16 – 19ºC (Gustaveson *et al.* 1984). All fish will be assessed for health, sexual maturity, weighed (± 10 g), and measured (TL; ± 1 mm). A temperature sensitive radio tag will be surgically implanted into each fish using methods described by Hart and Summerfelt (1975). All tagged individuals will be held long enough (overnight if necessary) to ensure good health before release into Lake Pleasant. Location and depth of fish will be monitored bi-weekly from time of release until July, then monthly until December. When a fish is located we will record its position with a GPS. The interval frequency of the tag will indicate the temperature the fish is occupying, enabling us to match that temperature to the temperature profile to determine the depth of the fish. The water quality profile will be measured at 1-m depth intervals from surface to bottom with a YSI model 610-DM meter. We will also record dissolved oxygen concentration (mg/L), specific conductivity ($\mu S \cdot cm^{-1}$) and pH to identify preferred water quality ranges.

GIS mapping of fish locations will indicate seasonal migrational patterns and habitat use of Lake Pleasant striped bass.

2.2 Determine seasonal habitat use by striped bass in Lake Pleasant.

Habitats where tagged fish are located will be classified as 'deep pelagic', 'shallow pelagic', 'littoral', 'Agua Fria', or 'other'. Size dependent (adult vs. sub-adult) and seasonal movement will be analyzed according to hypotheses derived from literature.

Hypothesis: i) Adult and sub-adult striped bass occupy 'deep pelagic' habitats during winter months.

ii) In late spring, mature striped bass migrate up the 'Agua Fria' to spawn, and return to the reservoir post-spawn.

iii) Adult and sub-adult striped bass occupy 'shallow pelagic' habitats in proximity to the thermocline during summer months when the reservoir is stratified.

iv) Adult striped bass do not utilize 'littoral' habitats.

Repeated measures analysis of variance (ANOVA; $\alpha = 0.05$) will be performed to compare frequencies of fish locations among the habitat types for spring, summer and winter seasons.

2.3 Determine striped bass reproductive success in Lake Pleasant.

2.3.1   Larval Tow Surveys

We will conduct larval surveys to determine presence/absence of striped bass eggs and larvae, thereby indicating if striped bass are naturally reproducing in Lake Pleasant. Bi-weekly larval fish and egg sampling will begin when water temperatures reach 16ºC (Gustaveson *et al.* 1984; Setzler *et al.* 1980) or when eggs or larvae are detected in water pumped from the canal into Lake Pleasant (Objective 3.0), and will continue until eggs and larvae are no longer collected. Two 1-m diameter conical (3:1 length to diameter ratio) 500 μm nets supported via a modified side-mounted portable push-net apparatus (Tarplee *et al.* 1979) on a 19-foot aluminum boat will be used to sample eggs and larvae. A General Oceanics Inc. (Model 2030R) digital-mechanical flow meter installed at the center of the mouth of each net will record the volume of water sampled. Nets will be set at a depth of ~ 0.3 m below water surface. On each bi-weekly sampling date, two runs parallel to shoreline, lasting 5-7 minutes each, will be conducted in each the lower basin, upper basin, and Agua Fria River, between the hours of 15:00 and 20:00. Flow volume and surface temperature (°C) will be recorded for each

run. Samples will be fixed in 10% formalin. In the laboratory, samples will be transferred to 10% ethanol, and ichthyoplankton will be identified to family (Centrarchidae, Cyprinidae, Clupeidae, Ictaluridae, Percichtyidae, and others) and enumerated.

2.3.2 Larval Light Trap Surveys

Ten larval light traps will be deployed bi-weekly on the same days that larval tows are conducted. The larval light traps are constructed four of clear PVC pipes with a slit cut longitudinally that are glued to a Styrofoam frame (top) and Plexiglas to allow a 4mm space between the pipes to allow larval fish to swim into the inner chamber. A string of three LED battery powered lights is lowered into the center of the pipes. The light trap is lowered into the water in littoral areas typically < 4 feet in depth, and anchored to the lake bottom with a weight to prevent it from being washed away. The Styrofoam enables the trap to float flush with the surface of the water while the PVC tubing is submerged below the water surface. The traps are deployed just prior to dusk and allowed to fish overnight. Larval fish are phototactic, and are attracted to the light, and swim through the 4 mm opening and are trapped in the PVC enclosure. Larger fish cannot enter the trap and are therefore unable to enter and prey on the larval fish. As the trap is pulled out, the water drains through a mesh container attached to the bottom of the frame which has a circular hole cut in it, leaving behind the any larval fish or zooplankton. Traps will be deployed in clusters of 2 – 3 just prior to sunset along the shoreline in waters less than 3 m in depth. Traps will be fished for 4 – 12 hours, and will be removed before dawn. Samples will be fixed in 10% formalin and returned to the laboratory for analysis. Ichthyoplankton will be enumerated and identified to family (Centrarchidae, Cyprinidae, Clupeidae, Ictaluridae, Percichtyidae, and others).

Observation of striped bass eggs and/or larvae will indicate that striped bass are successfully spawning in Lake Pleasant, assuming no significant inputs of striped bass eggs or larvae from the CAP canal (see Objective 3.0).

OBJECTIVE 3.0   DETERMINE MOVEMENT OF STRIPED BASS FROM THE CAP CANAL INTO LAKE PLEASANT THROUGH THE WADDELL INTAKE STRUCTURE

Eggs and young fish entrained from Lake Havasu are the primary source of fishes in the canal system, and in turn, these fish become potential seeds for the Lake Pleasant fishery. Movement of fish into and out of Lake Pleasant occurs through the New Waddell intake and outtake structures. Our goal is to determine if striped bass continue to enter Lake Pleasant from the CAP canal. We will therefore concentrate sampling efforts at the Waddell Dam, where water is pumped from the canal into the reservoir.

Research Hypothesis: Striped bass reproduce in the CAP canal and enter Lake Pleasant through the Waddell intake structure.

3.1 Sample movement of fish, larval fish and fish eggs through the Waddell Intake structure.

We will place a 500 μm net over the bottom slide gate of one intake structure on the Lake Pleasant side of the New Waddell dam (Figure 5). Striped bass in the canal will likely spawn before those in the reservoir, since water temperatures in canals will be warmer than in the reservoir. We will sample the water pumped from the canal into Lake Pleasant once every two weeks beginning in mid- February until eggs are no longer detected in samples, or pumping of water into Lake Pleasant stops (typically the beginning of April). Nets will be removed after 30 minutes, and samples will be washed into a sample jar, fixed in10% formalin and returned to the laboratory for identification to species and enumeration. Dimensions of the net will be based on those of the gate on the intake structure. Net mesh will be 500 μm, and a General Oceanics Inc. (Model 2030R) digital-mechanical flow meter will be installed at the center of the mouth of the net to measure the volume of water sampled. Mueller (1989) found that time of day made no difference when sampling eggs and larvae in the CAP canal, therefore we will collect the sample the same day as larval tows, prior to conducting the larval tows.
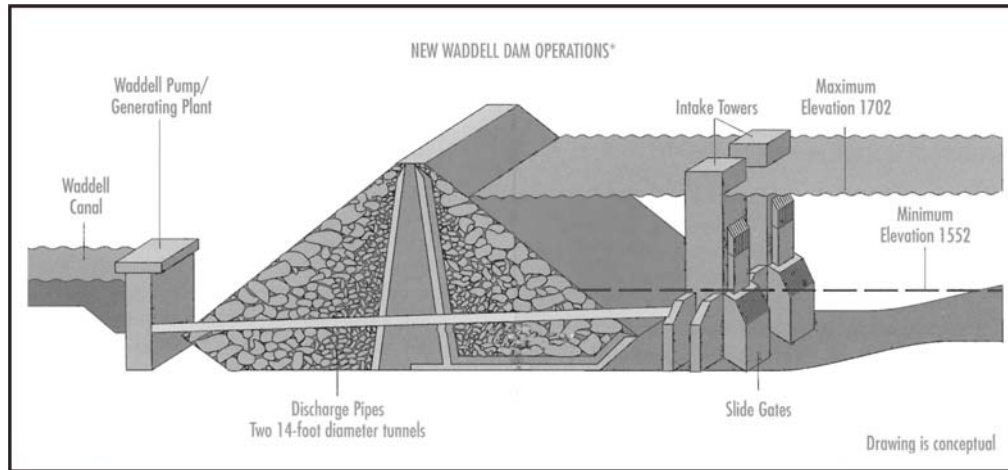
Figure 5. A 500 μm net will be secured over the bottom slide gate to sample for movement of fish, larval fish and eggs from the CAP canal into Lake Pleasant.

DELIVERABLES

Annual work plans and performance reports will be submitted to the US Fish and Wildlife Service. A final report that provides, in detail, all methods, results, discussions, and conclusions pertaining to the above outlined objectives will be submitted to the US Fish and Wildlife Service by 30 June 2007. Included in the report will be striped bass management recommendations for Lake Pleasant.

STUDY TIMELINE

Study Target	FY2004		FY2005				FY2006				FY2007			
	Jan - June 04		July - Dec 04		Jan - Jun 05		July - Dec 05		Jan - Jun 06		July - Dec 06		Jan - Jun 07	
	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
Water Quality		4-Apr	9-Aug	1-Nov	Feb		Aug	Nov	Feb		Aug	Nov		
Deploy/Collect Hobo Thermisters					Jan				Jan				Jan	
Hydroacoustic Surveys					Feb		Aug		Feb		Aug			
Gill Netting Surveys		April	2-Aug	Nov	Feb		Aug	Nov	Feb		Aug	Nov		
Electrofishing Survey				Nov	Feb		Aug	Nov	Feb		Aug	Nov		
Fish Aging			Aug - Dec				Aug - Dec				Aug - Dec		Jan	
Diet Analysis			Aug - Dec				Aug - Dec				Aug - Dec		Jan	
Telemetry Implantation					Jan				Jan					
Telemetry Monitoring					Jan - Jun		July - Dec		Jan - Jun		July - Dec			
L. Pleasant Larval Tows					Feb - May				Feb - May					
L. Pleasant Light Traps		May			Feb - May				Feb - May					
Waddell Dam Fish/Egg Passage									Feb - May					
Larval Fish Identification	May - Jun					Jun	July - Dec			Jun	July - Dec			
Annual Work Plan			Aug				Aug				Aug			
Data Analysis / Writing			Sep - Dec				Sep - Dec				Sep - Dec		Jan - Mar	Apr
Final Draft														1-May
Final Report														30-Jun

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